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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF	:
TOMOYOSHI ITO	: EXAMINER: CHANG, A. Y.
SERIAL NO: 10/500,461	:
FILED: JULY 14, 2004	: GROUP ART UNIT: 2872
FOR: MOVING-IMAGE HOLOGRAPHIC REPRODUCING DEVICE AND COLOR MOVING-IMAGE HOLOGRAPHIC REPRODUCING DEVICE	:

APPEAL BRIEF UNDER 37 CFR 41.37

COMMISSIONER FOR PATENTS
ALEXANDRIA, VIRGINIA 22313

SIR:

This is an appeal of the final Office Action dated April 22, 2008. A Notice of Appeal was filed on August 22, 2008.

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I. 41.37(C)(1)(I) Real Party of Interest

The real party of interest in this appeal is the assignee Japan Science and Technology Agency whose address is 1-8, Hon-Cho 4-Chome, Kawaguchi-shi, Saitawa 332-0012 Japan .

II. 41.37(C)(1)(II) Related Appeals and Interferences

There are no related interferences. There are no related appeals.

III. 41.37(C)(1)(III) Status of Claims

Claims 7 and 10-13 are pending and appealed. Claims 1, 4, 5-6, 8, and 9 are canceled.

Claims 7 and 10-11 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over the patent issued to Kato et al (U.S. Pat. No. 5,852,504) in view of Sekiguchi et al (U.S. Pat. No. 5,798,864) and in view of Popovich et al (U.S. Pat. No. 6,115,152) and Eichenlaub (U.S. Pat. No. 65,410,345). Claims 12 and 13 stand rejected under 35 U.S.C. § 102(a) as being unpatentable over Kato et al and Sekiguchi et al and Popovich et al and Eichenlaub in view of Fukagawa et al (U.S. Pat. No. 6,510,446) and Ohno (U.S. Pat. No. 6,232,940).

IV. 41.37(c)(1)(iv) Status of Amendments

An amendment was filed for this application on January 7, 2008 which resulted in the final Office Action dated April 22, 2008. An amendment after the final rejection was filed on July 22, 2008 canceling Claim 8. A Notice of Appeal was filed August 22, 2008.

V. 41.37(c)(1)(v) Summary of Claimed Subject Matter

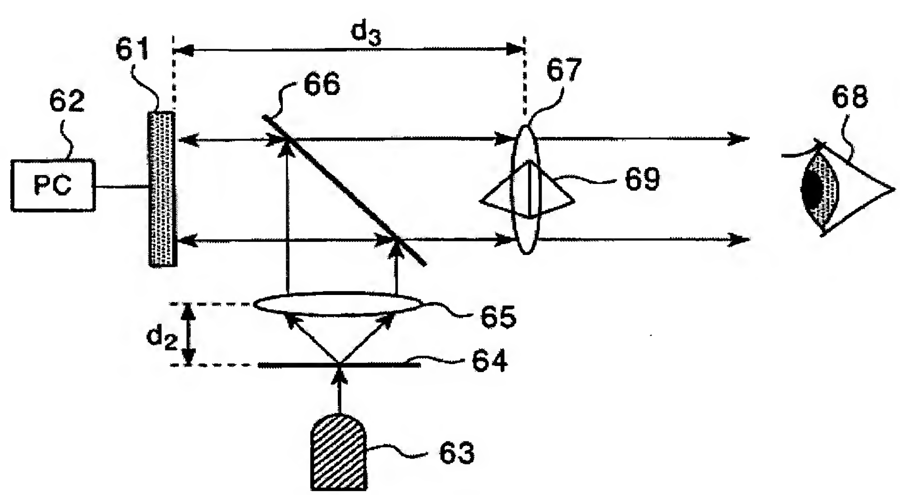
The following is a claim chart comparison of the claim elements to the disclosure in the specification.

Claim 7	**Support in U.S. Pat. Appl. No.** 10/500,461
A color moving-image holographic reproducing device comprising:	Specification, page 11, lines 4-9: Accordingly, it is an object of the present invention to provide a simple color moving-image holographic reproducing device that can reconstruct a high-resolution image by using a reflective liquid crystal display and further using a light-emitting diode as a reproducing light source. Specification, page 16, lines 14-17: Figure 3 is a block diagram of a moving-image holographic reproducing device including a reflective liquid crystal display and a light-emitting diode according to a first embodiment of the present invention.
(a) a computer configured to create a computer-generated hologram from three-dimensional coordinate data of a three-dimensional object which is externally obtained;	Specification, page 11 lines 16-23 : A moving-image holographic reproducing device includes a computer for creating a hologram from three-dimensional coordinate data, a reflective liquid crystal display for displaying the hologram, a half mirror for projecting the displayed hologram, and a light-emitting diode, wherein a reconstructed three-dimensional image is displayed by illuminating the half mirror with light emitted from the light-emitting diode. Specification, page 17, lines 19-21: A hologram is generated from three-dimensional coordinate data by the personal computer 2 and is then displayed on the reflective LCD 1.
(b) a reflective liquid crystal display connected to the computer and configured to display the-computer-generated hologram;	Specification, page 17, lines 19-21: A hologram is generated from three-dimensional coordinate data by the personal computer 2 and is then displayed on the reflective LCD 1. Specification, page 17, lines 22-25: The reflective LCD 1 is irradiated with the LED light 3A emitted from the LED 3 by using the beam splitter (half mirror) 6 to display a three-dimensional reconstructed image.

(c) a half mirror configured to project the displayed computer-generated hologram;	Specification, page 17, lines 22-25: The reflective LCD 1 is irradiated with the LED light 3A emitted from the LED 3 by using the beam splitter (half mirror) 6 to display a three-dimensional reconstructed image.
(d) three light-emitting diodes of primary colors red (R), green (G), and blue (B) (LEDs) functioning as reference light source; and	Specification, page 19, lines 15-23: As described above, a reflective LCD that can operate with LED-emitting incoherent light can provide the system with significant flexibility and cost reduction. Figure 5 is an example of reconstruction using LEDs for three primary colors of light, red (R), green (G), and blue (B), in a moving-image holographic reproducing device according to the first embodiment of the present invention. In the drawing, a direct beam of light is optically eliminated.
(e) the LEDs arranged on a two dimensional grid pattern and respectively emitting primary colors of light, red (R), green (G), and blue (B), at the same time,	Specification, page 33, line 19, to page 34, line 13: The main difference from the known technology described in (1) and (2) is that reference light sources, that is, a red (R) light source 63A, a green (G) light source 63B, and a blue (B) light source 63C are arranged in proximity to each other, as shown in Fig. 12(a). The R, G, and B light sources 63 emit light at the same time instead of emitting light in a time-multiplexing manner. The pinhole filter 64 is prepared for each of the R, G, and B light sources 63. This arrangement shifts optical axes of the three colors from each other. The color moving-image holographic reproducing device according to the present invention makes active use of the shift. Each beam of the R, G, and B light is reshaped into parallel light by the collimator lens 65. Since the R, G, and B light sources functioning as reference light sources are placed at different positions, each beam of parallel light is incident on the reflective LCD 61 at a different angle. Therefore, direct reflected light at the reconstruction position, which is a distance d.sub.3 (1000 mm) from the reflective LCD 61, is shown in Fig. 12(b).

wherein a first LED of the R, G and B LEDs is disposed in the vicinity of a second LED in the horizontal direction and a third LED is disposed in the vicinity of the second LED in the vertical direction orthogonal to the horizontal direction;	Specification, page 34, lines 14-21: The size of rectangular regions 69A, 69B, and 69C shown in FIG. 12(b) is d_5 (14.6 mm) by d_6 (10.4 mm), which is the same size as that of the LCD panel used in the embodiment. A shift distance d_7, between the colors is given by [distance d_1, between the reference light sources (8 mm)] $\div$[distance d_2 between the pinhole filter 64 and the collimator lens 65 (300 mm)] $\times$ [distance d_3 between the LCD 1 and the reconstruction position (1000 mm)]=27 mm.
wherein optical axes of color light beams from the LEDs are shifted from each other, the light beams are projected to the half mirror and onto the reflective liquid crystal display, and a color holographic image is formed from the computer-generated hologram.	Specification, page 12, line 22, to page 13, line 8: A color moving-image holographic reproducing device includes a computer for creating a single-plate hologram from three-dimensional coordinate data, a reflective liquid crystal display for displaying the single-plate hologram, a half mirror for projecting the displayed single-plate hologram, and three LEDs for functioning as reference light sources, the LEDs respectively emitting primary colors of light, red (R), green (G), and blue (B), at the same time, wherein optical axes of color light beams from the LEDs are shifted from each other, the light beams are projected to the half mirror, and a color holographic image is reconstructed with the single-plate hologram. See FIGs. 11 and 12 reproduced below.

FIG. 11



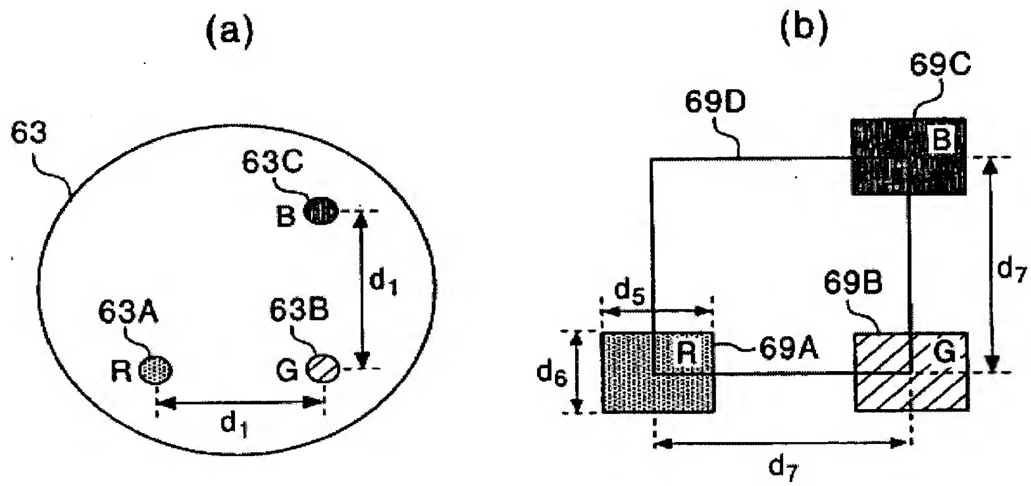


FIG. 12

VI. 41.37(C)(1)(VI) Grounds of Rejection for Review

Whether the rejection of Claims 7 and 10-11under 35 U.S.C. § 103(a) as being unpatentable over Kato et al in view of Sekiguchi et al and in view of Popovich et al and Eichenlaub should be reversed. Whether the rejection of Claims 12 and 13 under 35 U.S.C. § 102(a) as being unpatentable over Kato et al and Sekiguchi et al and Popovich et al and Eichenlaub in view of Fukagawa et al and Ohno should be reversed.

VII. 41.37(C)(1)(VII) ARGUMENTS

A. Regarding the 35 USC 103 Rejection of Claims 7 and 10-11

M.P.E.P. § 2141.02 requires that, for an examiner to rely on a reference under 35 U.S.C. § 103, the reference must be analogous art. The Court in In re GPAC Inc., 57 F.3d 1573, 35 USPQ2d 1116 (Fed. Cir. 1995), noted that:

> To support a finding that these twelve references are within the scope of the relevant prior art, we must therefore determine that they are analogous

> art that is "reasonably pertinent to the particular problem with which the inventor was involved." A reference is reasonably pertinent if, even though it may be in a different field of endeavor, it is one which, because of the matter with which it deals, logically would have commended itself to an inventor's attention in considering his problem. If a reference disclosure relates to the same problem as that addressed by the claimed invention, "that fact supports use of that reference in an obviousness rejection. [Citations removed]

In the present case, Appellant submits that problems with a color moving-image holographic reproducing device (i.e., the present invention) are not related to problems with stereoscopic imaging.

As shown in the evidence appendix (Article A), stereoscopic imaging is a technique in which a viewer sees different viewpoint images of an object through two eyes, the right and the left. In one example of stereoscopic imaging, optical elements such as lenticular sheets or parallax barriers are attached to display panels and they collect the left and right images displayed on the panel and deposit them at the appropriate eyes without any interference between them.

As also stated in the evidence appendix (Article A), holography is "totally different from the conventional stereoscopic approach." In general, holography is a technique that allows the light scattered from an object to be recorded and later reconstructed so that it appears as if the object is in the same position relative to the recording medium as it was when recorded. The image changes as the position and orientation of the viewing system changes in exactly the same way as if the object was still present, thus making the recorded image (hologram) appear three dimensional.

Therefore, although there may be some similarities in both techniques presenting to the eye three-dimensional type images, the optical constraints and the equipment configurations are quite different in scope and function. Because of these differences and constraints, the stereoscopic imaging techniques of <u>Eichenlaub</u> do not represent matter which

would have logically commended itself to ones attention if one were addressing Appellant's problem of electronically-derived holographs. Indeed, the examiner has in no way explained why problems with stereoscopic imaging are reasonably pertinent to a color moving-image holographic reproducing device.

Hence, for this reason alone, the obviousness rejection based on Eichenlaub should be reversed.

Furthermore, M.P.E.P. § 2143.03 requires that all words in a claim must be considered in judging the patentability of the claim against the prior art. Claim 7 defines:

> A color moving-image holographic reproducing device comprising:
> (a) a computer configured to create a computer-generated hologram from three-dimensional coordinate data of a three-dimensional object which is externally obtained;
> (b) a reflective liquid crystal display connected to the computer and configured to display the-computer-generated hologram;
> (c) a half mirror configured to project the displayed computer-generated hologram;
> (d) three light-emitting diodes of primary colors red (R), green (G), and blue (B) (LEDs) functioning as reference light source; and
> (e) the LEDs arranged on a two dimensional grid pattern and respectively emitting primary colors of light, red (R), green (G), and blue (B), at the same time, wherein a first LED of the R, G and B LEDs is disposed in the vicinity of a second LED in the horizontal direction and a third LED is disposed in the vicinity of the second LED in the vertical direction orthogonal to the horizontal direction;
> wherein optical axes of color light beams from the LEDs are shifted from each other, the light beams are projected to the half mirror and onto the reflective liquid crystal display, and a color holographic image is formed from the computer-generated hologram.

The final Office Action stated on pages 5 and 6:

> Kato et al teaches that the three light sources, (for generating red, blue and green light respectively), are arranged in a two-dimensional array manner, (please see Figure 36) each with an associated spatial light modulators. One skilled in the art would understand in order for each of the light beam to illuminate the spatial light modulator (SLM, 200, 202, 204, Figure 36), arranged in two dimensional manner, the light sources have to be arranged also

> in two dimensional manner, (i.e. the semiconductor light sources (206, 208, 210) have to be aligned with the optical axes of the SLM respectively), since the collimating light beams from the three light sources will not be able to turn direction by themselves or by SLM to form the orthogonal arranged light beams as they incident on the half mirror. However this reference does not teach that the three color light sources are arranged so that lights are emitted from a plane formed by the two dimensional light sources patterns. But one skilled in the art must understand that since the three primary color lights are used to illuminate the liquid crystal display device to produce full color display. The three color light beams have to be aligned with the arrangement of the color sub-pixels to produce the full color display. As demonstrated by Eichenlaub in a full color image display arrangement, light sources with red LED (174, Figure 13), green LED (175) and blue LED (176 and/or 177) are arranged in a two dimensional grid pattern with first LED (such as the blue LED, 177) at vicinity of the second LEDs (green LED 176) in the horizontal direction and a third LED (red LED 174) is at the vicinity of the second LED (green LED 176) at vertical direction, so that the light emitting diodes for the three primary color can be used to illuminate a pixel of the liquid crystal display to produce the full color image display. It would then have been obvious to one skilled in the art to arrange the three color light sources in a grid pattern that matches the pixels on the liquid crystal display for the benefit of using a single LCD display to efficiently illuminate the display to provide full color image display.

Appellant rebuts this position on obviousness on a number of separate grounds.

Firstly, the examiner's conclusion that it would have been obvious to "arrange the three color light sources in a grid pattern that matches the pixels on the liquid crystal display" is only relevant to the context of Eichenlaub where lights from the respective red, blue, and green pixels are focused by respective lenslets 179, 180, etc. to form a "fused" color image to an observer. See col. 12, line 45, to col. 13, line 9.

Accordingly, the Office Action only provided a conclusion on obviousness as to what would have been obvious in the stereoscopic imaging liquid crystal display techniques of Eichenlaub. Indeed, a modification of Kato et al is necessary because Kato et al only shows in Figure 36 (cited in the Office Action for an asserted teaching of light sources arranged in a two dimensional array manner) a linear arrangement of light sources. Kato et al does not

show the defined configuration of two LEDs in a first direction and a third LED in a direction orthogonal the first direction.

Accordingly, what is needed for a case of *prima facie* obviousness is an articulated reason as to why it would have been obvious at the time of Appellant's invention to modify Kato et al to arrive at the claimed features of first LED of the R, G and B LEDs disposed in the vicinity of a second LED in the horizontal direction and a third LED disposed in the vicinity of the second LED in the vertical direction orthogonal to the horizontal direction. Yet, the Office Action only provides a conclusion on obviousness as to what would have been obvious in the stereoscopic imaging liquid crystal display techniques of Eichenlaub.

Secondly, the ***on and off synchronization*** of the LEDs in Eichenlaub ***teaches away*** from the claimed invention. The Court in In re Gurley, 31 USPQ2d 1130 (Fed. Cir. 1994) stated that:

> A reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, or ***would be led in a direction divergent from the path that was taken by the applicant.*** The degree of teaching away will of course depend on the particular facts; in general, a reference will teach away if it suggests that the line of development flowing from the reference's disclosure is unlikely to be productive of the result sought by the applicant. [Emphasis added.]

In this case, Claim 7 defines that the LEDs are arranged on a two dimensional grid pattern and respectively emit primary colors of light, red (R), green (G), and blue (B), ***at the same time***, while Eichenlaub teaches ***on and off synchronization***. Thus, a person of ordinary skill, upon reading Eichenlaub, would be lead to use on and off synchronization and not the claimed emitting at the same time.

Thirdly, the light emitting elements in Eichenlaub (functioning in an on and off synchronization) can be considered to function differently than in the light emitting elements

in the claimed combination. In other words, the claimed elements in combination do **not** function as each element separately functions in Eichenlaub.

Guidelines for the Patent and Trademark Office, published in Federal Register Vol. 72, No. 195, on Wednesday October 10, 2007entitled: "Examination Guidelines for Determining Obviousness under 35 U.S.C. 103 in View of the Supreme Court Decision in KSR International v. Teleflex Inc," indicate that:

> Office personnel should consider all rebuttal evidence that is timely presented by the applicants when reevaluating any obviousness determination. Rebuttal evidence may include evidence of "secondary considerations," such as "commercial success, long felt but unsolved needs, [and] failure of others", and may also include evidence of unexpected results. Office personnel must articulate findings of fact that support the rationale relied upon in an obviousness rejection. As a result, applicants are likely to submit evidence to rebut the fact finding made by Office personnel. For example, in the case of a claim to a combination, applicants may submit evidence or argument to demonstrate that:
>
> (1) one of ordinary skill in the art could not have combined the claimed elements by known methods (e.g., due to technological difficulties);
>
> (2) the elements in combination do not merely perform the function that each element performs separately; or
>
> (3) the results of the claimed combination were unexpected.
>
> Once the applicant has presented rebuttal evidence, Office personnel should reconsider any initial obviousness determination in view of the entire record. All the rejections of record and proposed rejections and their bases should be reviewed to confirm the continued viability. The Office action should clearly communicate the Office's findings and conclusions, articulating how the conclusions are supported by the findings.

Here, as detailed above, the elements (the LEDs of Eichenlaub) if applied in combination with Kato et al to deprecate the invention and emit at the same timedo not merely perform the function that the LEDs of Eichenlaub performed separately (functioning in an on and off synchronization).

Hence, Appellant has presented rebuttal evidence for 1) the improper application of non-analogous art, 2) a failure of the Office to provide a reason as to why it would be

obvious to modify Kato et al, 3) teaching away in the art from simultaneous emission from different color light sources, and 4) why the claimed elements in combination do not function as each element separately functions in Eichenlaub.

Hence, for all these reason, the 35 U.S.C. § 103(a) rejection of Claims 7 and 10-11 should be reversed.

b. Regarding the 35 USC 103 Rejection of Claims 12 and 13

Claim 12 defines that the claimed color moving-image holographic reproducing device includes a dedicated high-speed parallel distributed processing system including a plurality of dedicated Large Scale Integrator LSIs ***between the computer and the reflective liquid crystal display***. Claim 13 defines that the dedicated high-speed parallel distributed processing system further comprises a shared memory for storing coordinates of an object, and defines that the plurality of dedicated LSI's are configured in parallel.

The final Office Action asserts on page 6 that Claims 12 and 13 fail to provide the logical relationships of these elements with the holographic reproducing device. Yet, as noted above, Claim 12 (and thus Claim 13 which depends from Claim 12) defines a plurality of dedicated Large Scale Integrator LSIs ***between the computer and the reflective liquid crystal display***. See Appellant's Figure 6 as one example.

Apparently, because the Office Action apparently gave no consideration to the claimed location of ***between the computer and the reflective liquid crystal display***, these features were not shown to be in any of the applied art cited. As such, all words in Claims 12 and 13 have not been considered in judging the patentability of the claim against the prior art. Furthermore, there exists no articulated reasoning with some rational underpinning to support the legal conclusion of obviousness with regard to why it would have been obvious at the

time the invention was made to position the plurality of dedicated Large Scale Integrator LSIs between the computer and the reflective liquid crystal display.

The Guidelines for the Patent and Trademark Office, published in Federal Register Vol. 72, No. 195, entitled: "Examination Guidelines for Determining Obviousness under 35 U.S.C. 103 in View of the Supreme Court Decision in KSR International v. Teleflex Inc," indicate that:

> The key to supporting any rejection under 35 U.S.C. 103 is the clear articulation of the reason(s) why the claimed invention would have been obvious. The Supreme Court in KSR noted that the analysis supporting a rejection under 35 U.S.C. 103 should be made explicit. The Court quoting In re Kahn 41 stated that " '[R]ejections on obviousness cannot be sustained by mere conclusory statements; instead, ***there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness.***' "

Hence, for this additional reason (besides their dependence from allowable claims), the 35 U.S.C. § 103(a) rejection of Claims 12 and 13 should be reversed.

VII. 41.37(c)(1)(vii) Claims Appendix Of Claims Involved In Appeal

Attached herewith is a Claims Appendix.

IX. 41.37(C)(1)(IX) Evidence Appendix

Attached herewith is one reference article: " Emerging 3D Display Technologies; Holographic 3D, Volumetric 3D and Spatial 3D Displays"

X. 41.37(c)(1)(x) Related Proceedings Appendix

There are no related proceedings.

XI. Conclusion

Appellant request on the basis of the arguments presented above that the outstanding grounds for the rejection be reversed.

Respectfully submitted,

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CLAIMS APPENDIX

1-6 (Cancelled).

7. A color moving-image holographic reproducing device comprising:

(a) a computer configured to create a computer-generated hologram from three-dimensional coordinate data of a three-dimensional object which is externally obtained;

(b) a reflective liquid crystal display connected to the computer and configured to display the-computer-generated hologram;

(c) a half mirror configured to project the displayed computer-generated hologram;

(d) three light-emitting diodes of primary colors red (R), green (G), and blue (B) (LEDs) functioning as reference light source; and

(e) the LEDs arranged on a two dimensional grid pattern and respectively emitting primary colors of light, red (R), green (G), and blue (B), at the same time, wherein a first LED of the R, G and B LEDs is disposed in the vicinity of a second LED in the horizontal direction and a third LED is disposed in the vicinity of the second LED in the vertical direction orthogonal to the horizontal direction;

wherein optical axes of color light beams from the LEDs are shifted from each other, the light beams are projected to the half mirror and onto the reflective liquid crystal display, and a color holographic image is formed from the computer-generated hologram.

8- 9 (Cancelled).

10: The color moving-image holographic reproducing device according to Claim 7, wherein each of the R, G, and B LEDs has a pinhole filter and emits light to a collimator lens to generate parallel light, and the half mirror is illuminated with the parallel light.

11: The color moving-image holographic reproducing device according to Claim 10, wherein the size of a color reconstruction area is determined in accordance with a distance d_1 of the second LED to the first LED and the third LED, a distance d_2 between the pinhole filter and the collimator lens, and a distance d_3 between the reflective liquid crystal display and a field lens that produces a reconstructed image.

12. The color moving-image holographic reproducing device according to Claim 7, further comprising:

a dedicated high-speed parallel distributed processing system including a plurality of dedicated Large Scale Integrator LSIs between the computer and the reflective liquid crystal display.

13. The color moving-image holographic reproducing device according to Claim 12, wherein:

the dedicated high-speed parallel distributed processing system further comprises a shared memory for storing coordinates of an object, and

the plurality of dedicated LSI's are configured in parallel.

EVIDENCE APPENDIX

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Opinion - Issue No.: **200710 (#4420)** (3)- Hit: 43

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Emerging 3D Display Technologies; Holographic 3D, Volumetric 3D and Spatial 3D Displays

This is the second of a six part series on all aspects of emerging 3D Display Technologies, Systems, Applications and Markets -- Ed.

By Kim Eun-soo
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Kim Eun-Soo, Director of 3DRC and Professor at Kwangwoon University

Human beings see the different viewpoint images of an object through two eyes, the right and left. Then, the human brain recognizes the 3D stereopsis of the object by synthesizing them with the binocular disparity of a stereo input image pair. Most conventional 3D display systems have been implemented by imitating this human visual system, which includes stereoscopic and autostereoscopic 3D displays. In case of stereoscopic 3D displays, the viewer is required to wear special glasses such as anaglyphs, polarized or shutter glasses for separated reception of the left and right images on the eyes. But in auto-stereoscopic 3D displays a 3D image can be presented to the viewer without the need for any special glasses. Optical elements such as lenticular sheets or parallax barriers are attached to display panels and they collect the left and right images displayed on the panel and deposit them at the appropriate eyes without any interference between them.

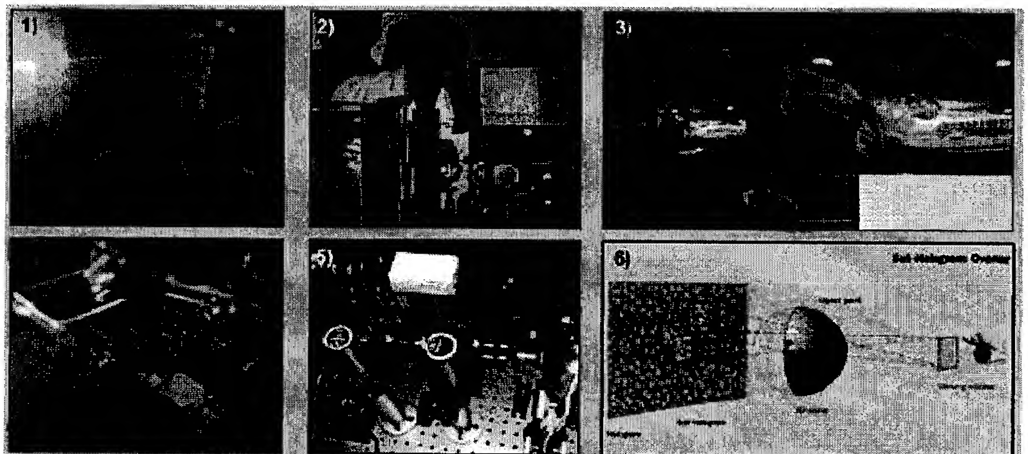
But, whether they are stereoscopic or auto-stereoscopic 3D displays, these approaches have been the cause of some fundamental problems such as eye fatigue and dizziness since C. Wheatstone invented the first Stereoscope in 1843. This is the main shortcoming of the technology, and the main reason why they still can't gain wide acceptance until now. The ultimate goal of 3D R&D is to develop a technology that can display a lifelike 3D image in real space having an image quality comparable to that of a highdefinition 2D image without requiring the viewer to wear any special glasses. Eventually, this advance will provide the viewers with the feeling of being present in the scene.

For that purpose some real 3D display technologies have been developed. One of them is the hologram. This holographic 3D display, which is totally different from the conventional stereoscopic approach, has been regarded as one of the attractive approaches for creating the most authentic illusion for observing volumetric 3D objects. It is because holographic technology can supply high-quality images and accurate depth cues viewed by human eyes without any special observation devices.

Holography was developed by D. Gabor in 1947. He recognized that when a suitable coherent reference wave is present simultaneously with the light scattered from a 3D object, then information about the amplitude and phase of the scattered waves can be recorded, in spite of the fact that recording media responds only to light intensity. He demonstrated that,

from such a recorded interference pattern, which he called a hologram, meaning a total recording, an image of the original 3D object can ultimately be obtained.

However, recording a hologram of a real object requires some wave interference between two laser beams with a high degree of coherence between them in a dark room. Therefore, this system must be kept very stable since even a very slight movement can destroy the interference fringes, in which both intensity and phase information of the 3D object are contained. These requirements, together with the development and printing processes, have prevented conventional holography from becoming widely employed in the field. As a solution for these limitations of conventional holography, a computer-generated hologram (CGH) has been suggested.



1) Historic laser transmission, pulsed portraits of Dr. Dennis Gabor, inventor of holography
2) DMD-based display of dynamic holographic images at the University of Texas
3) Full-color 3D images generated by large pixel-count CGH systems at QinetiQ Laboratories
4) Holographic video display system-Mark III at MIT
5) Incoherent holographic 3D display system from 3DRC
6) Sub-hologram-based holographic display system from SeeReal Technologies

A CGH is a digital hologram generated by computing the interference pattern produced by the object and the reference waves. Using this CGH pattern, an electro- holographic 3D display system can be constructed. In this approach, a ray-tracing method has been originally employed for calculating the contributions at the hologram plane from each object point source. That is, an object image to be generated can be approximated as a collection of self-luminous points of light, therefore the fringe patterns for all object points are calculated with the ray-tracing method and added up to obtain the whole interference pattern of the object image.

Now, CGH is regarded as an emerging technology, made possible by increasingly powerful computers, that avoids the interferometric recording step in conventional hologram formation. Instead, a computer calculates a holographic fringe pattern that it then uses to set the optical properties of a spatial light modulator (SLM), such as a liquid crystal microdisplay. The SLM then diffracts the readout light wave in a manner similar to the standard hologram to yield the desired optical wavefront.

Compared to conventional holographic approaches, CGH does not rely on the availability of specialized holographic recording materials and it can synthesize optical wavefronts without having to record a physical manifestation of them, and offers unprecedented wavefront control by making it easy to store, manipulate, transmit, and replicate holographic data. Although CGH-based display systems can be built today, their high cost makes them impractical for many applications. However, as the computer and optical hardware costs decrease, CGH displays will become a viable alternative in the near future.

CGH provides flexible control of light, making it suitable for a wide range of display types, including 2D, stereoscopic, auto-stereoscopic, volumetric, and true 3D imaging. CGH-based display technology can produce systems with unique characteristics impossible to achieve with conventional approaches.

In 2003, the University of Texas suggested the possibility of the display of dynamic holographic images by computing the holograms of objects in a threedimensional scene and then transcribing the 2D digital hologram onto a digital micro-mirror device (DMD) illuminated with coherent light. In 2005, QinetiQ laboratories of the United Kingdom presented true full-color 3D images generated using the specially-designed large pixel-count CGH systems. They calculated computergenerated holograms using a 102-node PC Linux cluster of dual IA-32 Pentium III 1.26-GHz Tualatin-core 512-Kb cache CPUs, with 1 Gb of memory per node and two 36-Gbyte Ultra160 SCSI disk drives, along with a Myrinet interconnect and a 7.5-Tbyte storage area network. They showed monochromatic and color, fullparallax 3D images produced by a computer generated hologram having 108 pixels.

In 2007, a team of MIT scientists developed a prototype for a small, inexpensive, holographic video system that works with consumer computer hardware such as PCs or gaming consoles, thereby enabling users to view images in three dimensions. The Mark III is the third generation of holographic video displays that MIT has developed since the early 1990s and it currently offers only monochromatic images, and its viewing volume is equivalent to an 80-mm cube, too small for practical applications such as PCs.

3DRC in Kwangwoon University also developed an incoherent holographic video system using a modified triangular interferometer. In this system, complex holograms without bias and conjugate images for 3D objects can be obtained by controlling the combination of wave plates and, through optical reconstruction of this complex hologram by a modified Mach- Zehnder interferometer, 3D images can be viewed.

More recently, SeeReal Technologies of Germany demonstrated a new holographic display at the SID 2007 conference. This holographic display prototype uses a 20 inch display that shows a real high-resolution 3D image in front of the screen. SeeReal Technologies uses a 30x30 pixel array for each of the 3D scene points, the so-called sub-hologram approach.

The versatility of CGH, combined with its unique ability to produce full-depth-cue 3D images at beyond eye resolution, floating in space, and with an extended color gamut has led some to label CGH the ultimate display technology. However, many CGH-based displays have an appetite for pixels that can far exceed other display types. Unique additional computational operations add to the cost of such systems, particularly high-frame-rate interactive systems. Thus, for many applications, lower-cost, simpler display technologies will be more appropriate. Nevertheless, with computer systems and display hardware continuing to decrease in price and other required technologies rapidly advancing, the question is not whether CGH systems will become a practical generic display technology but, rather, how soon.

RELATED PROCEEDINGS APPENDIX

None